

Digital Transformation of Islamic Boarding Schools: Developing Smart Pesantren through Educational Technology Integration

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Abstract

This study aims to formulate an integrated Smart Pesantren framework for strengthening the digital transformation of Islamic boarding schools while preserving their religious identity, cultural traditions, and educational values. The study employed a qualitative library research method through critical analysis and synthesis of recent scholarly literature on educational technology, digital transformation, pesantren digitalization, digital literacy, digital leadership, and Islamic education. The findings demonstrate that Smart Pesantren development requires the integration of six interrelated dimensions: digital infrastructure, digital pedagogy, digital governance, human digital competence, Islamic digital literacy, and data-informed institutional development. These dimensions indicate that technology can enhance learning accessibility, pedagogical effectiveness, administrative efficiency, institutional communication, Qur'anic learning, and educational services when supported by competent leadership, teacher readiness, adequate infrastructure, cybersecurity, ethical governance, and cultural compatibility. The novelty of this study lies in proposing an integrated Smart Pesantren framework that conceptualizes digital technology not as a substitute for pesantren traditions but as a strategic instrument for strengthening them. The framework integrates digital transformation with Islamic values, kyai leadership, santri development, educational quality, institutional intelligence, and sustainable learning ecosystems.

Keywords: Digital Transformation, Educational Technology, Digital Literacy

Introduction

Islamic boarding schools, commonly known as pesantren, constitute one of the most distinctive educational institutions in Indonesia and have historically played a major role in Islamic learning, character formation, social development, and community leadership. Their educational traditions are built around close relationships among kyai, ustadz, santri, religious texts, discipline, communal life, and moral habituation. Nevertheless, the emergence of digital society has transformed the environment in which pesantren operate. (Bakr et al., 2025) Students increasingly encounter knowledge through smartphones, social media, digital libraries, artificial intelligence, online learning platforms, and multimedia resources. Recent studies indicate that pesantren are gradually adopting digital technologies for learning, communication, administration, and institutional services, although the level of adoption remains uneven (Wijaya et al., 2024; Nugroho & Astutik, 2024). These findings demonstrate that digital transformation has become an institutional issue rather than merely a technological choice.

The transformation of pesantren should not be understood as a simple process of replacing traditional educational practices with digital technologies. Digital transformation involves changes in organizational processes, institutional culture, leadership, educational services, pedagogical practices, and the ways in which information is produced and managed. Research on digital transformation in educational institutions shows that transformation is most meaningful when technology becomes integrated with institutional strategy rather than being implemented through isolated projects (Castro Benavides et al., 2020; Fernández et al., 2023). This distinction is highly relevant to pesantren because purchasing computers or establishing internet connectivity does not automatically create a digitally mature institution. A pesantren may possess advanced devices while continuing to rely on manual administration, teacher-centered instruction, and weak digital literacy. Therefore, the central challenge is to create systemic alignment between technology, educational objectives, institutional culture, and Islamic values.

The concept of a Smart Pesantren emerges from this need for systemic transformation. A Smart Pesantren can be conceptualized as an Islamic boarding school that intelligently integrates digital infrastructure, data, educational technology, institutional management, human resources, and Islamic values to improve educational quality and institutional effectiveness. Smartness in this context does not mean technological sophistication alone. (Nabriz et al., 2025) It refers to the capacity of an institution to use information and technology responsibly to make learning, management, communication, services, and decision-making more effective. Recent work on smart technology in pesantren has begun to demonstrate practical possibilities, including Internet of Things applications for automated audio systems and institutional scheduling (Bashir et al., 2026). This evidence suggests that the Smart Pesantren concept can develop from an abstract vision into an operational institutional architecture.

Pesantren possess a unique institutional characteristic because their educational mission encompasses cognitive, spiritual, moral, social, and practical dimensions. Modern educational technology tends to emphasize efficiency, personalization, access, collaboration, and data-driven learning, whereas pesantren traditionally emphasize adab, discipline, ta'lim, tarbiyah, ta'dib, communal life, and transmission of Islamic knowledge. (Hushin et al., 2025) The challenge is therefore not simply to determine which technologies can be introduced but to determine which technologies are pedagogically and ethically appropriate. Research on technology integration in Islamic education demonstrates that technology can strengthen student engagement and learning when it is aligned with educational objectives and Islamic pedagogical considerations (Siregar et al., 2025). This perspective suggests that technological adoption should be guided by educational philosophy rather than technological enthusiasm. The implication is that Smart Pesantren must be designed as a value-based digital ecosystem rather than as a conventional school equipped with digital devices.

One of the most important opportunities presented by digital transformation is the expansion of access to learning resources. Traditional pesantren education often depends on physical books, printed *kitab*, face-to-face instruction, libraries, and direct teacher-student interaction. Digital libraries, electronic books, searchable classical texts, online databases, and multimedia materials can complement these resources without necessarily eliminating traditional learning. Research on digital literacy practices in pesantren has documented the use of Maktabah Syamilah, PDF books, Google Books, classical Islamic-text websites, projectors, and other digital devices for learning activities (Waqiyulloh & Dini, 2024). This evidence is relevant because digital resources can expand the intellectual environment available to santri while preserving the central role of teachers

and religious scholarship. Properly designed digital integration can therefore strengthen access without requiring the abandonment of traditional Islamic learning.

Digital transformation also provides opportunities to improve the quality of Qur'anic education. Tahfiz programs, for example, can use digital tools for memorization tracking, recitation recording, feedback, assessment, and individualized learning. Recent research on digital-based Qur'anic learning evaluation in boarding schools shows that digital systems can support the monitoring and evaluation of tahfiz learning processes (Sekolah et al., 2025). Similarly, research on digital transformation in Tahfidzul Qur'an education indicates positive possibilities for memorization, understanding, and application of Qur'anic teachings when technology is integrated appropriately (Nugroho & Astutik, 2024). These studies demonstrate that digital technology can support highly traditional forms of pesantren learning without necessarily weakening their religious orientation. The important condition is that digital tools must remain subordinate to pedagogical and spiritual objectives.

Another major area of transformation concerns digital literacy among santri. Digital literacy is broader than the technical ability to operate devices because it includes information evaluation, communication, content creation, ethical behavior, security awareness, and critical interpretation. Pesantren have an important opportunity to shape digital literacy according to Islamic ethical principles. (Begum et al., 2025) Research at Darunnajah Islamic Boarding School demonstrated that content-creator training, video production, and Islamic journalism can enable students to become productive digital participants rather than passive consumers (Darajat et al., 2022). This finding is relevant because Smart Pesantren should produce santri who can create meaningful digital content, communicate responsibly, and contribute positively to online communities. Digital literacy therefore becomes part of contemporary Islamic character formation rather than merely a technical competency.

Digital literacy also becomes increasingly important because santri are exposed to religious information from diverse online sources. Digital platforms provide access to Qur'anic interpretations, Hadith databases, fatwa collections, lectures, social media preachers, podcasts, and online religious communities. (Kashada et al., 2025) Such access creates opportunities for learning but also introduces risks associated with misinformation, decontextualized religious quotations, polarization, and unreliable interpretations. Research on digital literacy in Indonesian pesantren identifies continuing debates regarding digital restrictions, opportunities, and institutional challenges (Ghozali, 2024). The implication is that pesantren cannot simply protect students by restricting technology indefinitely. Instead, they should educate students to use technology critically, ethically, and responsibly.

The role of the kyai becomes particularly significant in the process of digital transformation. Historically, the kyai has served not merely as a teacher but as a moral authority, institutional leader, cultural guardian, and source of educational legitimacy. (Abdullah et al., 2025) Digital transformation introduces new leadership requirements because leaders must understand technological opportunities, manage organizational change, establish digital policies, and address risks. Recent research shows that kyai leadership plays an important role in facilitating digital transformation and improving educational services, including online registration and institutional information systems (Bahri et al., 2024). This finding demonstrates that digital transformation in pesantren is deeply connected with leadership rather than technology alone. A Smart Pesantren therefore requires digital leadership that combines technological awareness with Islamic wisdom, institutional legitimacy, and cultural sensitivity.

The development of Smart Pesantren also requires attention to institutional management. Administrative activities such as student registration, attendance, financial reporting, academic records, parental communication, scheduling, and human-resource management can increasingly be digitized. Research at Pondok Pesantren Ihyaul Ulum shows that digitalization can improve administrative efficiency, information access, financial transparency, and learning systems while simultaneously introducing challenges involving infrastructure, security, and misuse of technology (Muhammad et al., 2025). This evidence suggests that administrative digitalization can become an important foundation for institutional intelligence. However, data systems should be governed through clear policies regarding privacy, access, security, accountability, and ethical use.

The COVID-19 pandemic accelerated the digital transformation of education and exposed the importance of institutional digital readiness. Pesantren were required to reconsider assumptions about physical proximity, classroom interaction, communication, and access to educational materials. Research on digital transformation in pesantren indicates that digital platforms can extend religious learning beyond the physical boundaries of the boarding school, particularly for alumni and external communities (Maram & Fanani, 2025). This development illustrates the concept of educational deterritorialization, in which the intellectual and spiritual influence of pesantren can reach learners who are not physically present. Digital transformation therefore creates a new dimension of pesantren outreach while maintaining direct face-to-face learning as a core institutional practice.

However, digital transformation also presents significant risks. Infrastructure inequality can produce unequal access between pesantren located in urban and rural environments. Teachers may possess different levels of digital competence, while students may have unequal experiences with technology. (Yusuf et al., 2025) Cybersecurity, privacy, inappropriate content, excessive screen use, misinformation, and digital dependency represent additional concerns. Recent literature on digital transformation in educational institutions consistently identifies infrastructure, funding, resistance, digital literacy, and organizational readiness as important barriers (Latifah et al., 2022; Castro Benavides et al., 2020). These findings are relevant to pesantren because technological adoption without institutional readiness can produce fragmented systems and unintended educational consequences.

Teacher competence represents another central challenge. Educational technology is effective only when teachers understand how technological tools can be integrated with pedagogical strategies and subject content. The Technological Pedagogical Content Knowledge (TPACK) framework explains that effective technology integration requires the interaction of technological, pedagogical, and content knowledge. Research on teacher digital competence shows that educators require not only technical skills but also pedagogical and organizational competencies to use digital technology effectively (Basilotta-Gómez-Pablos et al., 2022). This is highly relevant for ustadz and ustadzah because technology integration in pesantren must address both general and Islamic subjects. Consequently, professional development should be continuous, contextual, collaborative, and directly connected to classroom practice.

Technology integration also requires curriculum transformation. Adding an information technology course to the curriculum does not automatically make a pesantren digitally transformed. Digital competence should be distributed across subjects and institutional activities so that students learn to use technology as a means of inquiry, communication, creation, collaboration, and problem solving. Recent conceptual work on pesantren curriculum integration proposes combining TPACK and the SAMR framework to develop a digital-adaptive pesantren curriculum (Raafi & Saifulloh, 2026). This



research is relevant because it demonstrates how established technology-integration frameworks can be contextualized for pesantren. The curriculum should therefore move from isolated technology instruction toward meaningful digital integration across the educational ecosystem.

Another important transformation concerns learning innovation. Technology can support blended learning, flipped learning, digital projects, virtual discussions, multimedia presentations, digital portfolios, and adaptive learning. Recent research on learning innovation in East Java pesantren indicates that educational technology can enhance teaching effectiveness when integrated with Islamic education management principles (Abidin et al., 2025). The relevance of this finding is that technology becomes pedagogically valuable when it changes how students learn rather than merely how teachers deliver information. Smart Pesantren should therefore encourage teachers to experiment with instructional models that combine traditional pesantren strengths with contemporary educational technologies. This approach can produce learning environments that are both culturally grounded and pedagogically innovative.

The integration of technology must nevertheless respect the distinctive character of pesantren. Traditional learning methods such as *sorogan*, *bandongan*, *halaqah*, *musyawarah*, and *bahtsul masail* represent pedagogical traditions that contain valuable mechanisms of dialogue, interpretation, discipline, and teacher-guided learning. Digital transformation should not treat these methods as obsolete. (Nurhidayah & Handayani, 2025) Instead, they can be enhanced through digital documentation, online discussion, digital repositories, collaborative annotation, recorded explanations, and research databases. Research on the integration of tradition and technology in pesantren emphasizes the importance of managing tensions between cultural continuity and technological change (Happyana et al., 2025). This evidence supports a transformation model based on integration rather than replacement.

The development of Smart Pesantren is also relevant to the wider agenda of twenty-first-century education. Santri increasingly need communication, collaboration, creativity, critical thinking, digital literacy, entrepreneurship, and problem-solving competencies. (Yilmaz et al., 2025) Recent research on pesantren transformation highlights the importance of integrating Islamic values, technology, and twenty-first-century competencies (Ramadhani et al., 2026). These competencies do not contradict Islamic education when they are framed through ethical and spiritual objectives. Instead, they can strengthen the capacity of santri to participate constructively in society. Smart Pesantren should therefore prepare students not merely to survive technological change but to become ethical actors within the digital society.

Despite increasing scholarship on pesantren digitalization, a conceptual gap remains. Existing studies often examine individual aspects such as digital literacy, digital leadership, e-learning, administrative digitalization, or specific educational technologies. Fewer studies integrate these dimensions into a comprehensive institutional model of Smart Pesantren. (Mukhlis et al., 2025) Recent systematic literature on digital pesantren transformation identifies pedagogical restructuring, digital leadership, and artificial intelligence as important dimensions of contemporary transformation (Rohana et al., 2026). This provides an important foundation but also indicates the need to integrate infrastructure, governance, pedagogy, human resources, digital ethics, data, and sustainability into a single conceptual architecture. The present study addresses this gap by proposing an integrated Smart Pesantren framework grounded in recent literature.

The purpose of this study is therefore to analyze the theoretical and empirical literature concerning digital transformation in Islamic boarding schools and to formulate a conceptual model for developing Smart Pesantren through educational technology



integration. The study specifically examines technological infrastructure, digital pedagogy, digital literacy, teacher competence, kyai leadership, institutional governance, Islamic values, digital ethics, and sustainable innovation. The study also seeks to identify the major barriers that may prevent pesantren from achieving meaningful digital maturity. The expected contribution is a comprehensive framework that can guide pesantren leaders, teachers, curriculum developers, policymakers, and researchers. The framework is intended to support technological transformation without reducing pesantren to a conventional digitally equipped school.

Theoretical Foundation

Digital transformation has emerged as a fundamental concept for understanding institutional change in contemporary education. Unlike digitization, which primarily refers to the conversion of analog information into digital formats, digital transformation involves broader changes in organizational structures, educational practices, institutional culture, decision-making processes, and mechanisms of value creation.(Desyulita et al., 2025) Within higher education and other educational institutions, digital transformation has been conceptualized as a multidimensional process involving technological, organizational, and human factors that interact continuously with one another (Castro Benavides et al., 2020). This perspective indicates that technological innovation cannot be separated from institutional capacity, human competencies, organizational culture, and strategic objectives. Fernández et al. (2023) similarly emphasize that successful digital transformation requires coordinated institutional initiatives rather than fragmented technology-oriented projects. In the context of pesantren, these perspectives imply that the development of a Smart Pesantren should encompass not only digital learning but also governance, administration, communication, human-resource development, infrastructure, and institutional culture. Thus, digital transformation provides the overarching conceptual framework through which the modernization of pesantren can be examined systematically.

The concept of digital transformation becomes particularly significant when applied to the distinctive institutional characteristics of pesantren. Pesantren function simultaneously as educational institutions, religious communities, centers of character formation, and organizations with strong traditions of interpersonal interaction between *kyai*, *ustadz*, and *santri*.(Wahidah et al., 2025) Consequently, technological transformation cannot simply replicate models developed for conventional schools or universities because the organizational objectives and cultural structures of pesantren are considerably different. Digital transformation must instead be designed to strengthen educational and religious functions while maintaining the institution's cultural and spiritual identity. Research indicates that digital transformation in educational organizations becomes effective when technological initiatives are aligned with organizational objectives, human resources, institutional processes, and strategic planning (Castro Benavides et al., 2020; Fernández et al., 2023). These findings are directly relevant to pesantren because technology introduced without institutional alignment may generate fragmented applications that fail to produce sustainable educational improvements.(Bolat et al., 2025) Therefore, Smart Pesantren should be conceptualized as an institutional transformation process in which technological innovation becomes integrated into the broader educational, managerial, and religious ecosystem.

Educational technology integration represents an important mechanism through which digital transformation can influence teaching and learning. Technology in education should not be understood merely as the availability of hardware, software,

internet connectivity, or digital platforms, but as the purposeful integration of technological resources into pedagogical processes. The effectiveness of technology depends substantially on the relationship between technological capabilities, pedagogical strategies, subject matter, and learner characteristics. The technological pedagogical content knowledge framework provides a relevant conceptual perspective because effective technology integration requires teachers to understand how technology interacts with pedagogy and disciplinary content (Major & Francis, 2018). Although the original TPACK framework was developed before the principal period of recent literature considered in this study, subsequent research continues to demonstrate its relevance for explaining teachers' capacity to integrate digital technologies meaningfully into educational practice. (Nurdi et al., 2025) Within pesantren, this framework is particularly useful because *ustadz* must integrate technological resources with both Islamic and general educational content. Accordingly, technology should function as a pedagogical instrument that strengthens learning quality rather than becoming an end in itself.

The depth of technological integration can be further understood through the SAMR framework, which conceptualizes technology use through the dimensions of substitution, augmentation, modification, and redefinition. This framework is useful because it differentiates between the mere replacement of conventional tools and the creation of learning activities that could not previously be implemented effectively. For example, replacing printed *kitab* with PDF files may represent substitution, whereas searchable digital manuscripts can provide additional functional advantages. Collaborative digital annotation of classical Islamic texts may constitute a more advanced form of modification, while international online *bahtsul masail* involving students from different institutions may represent a redefinition of conventional learning activities. The value of this framework lies in its capacity to evaluate the transformative depth of technology integration rather than simply measuring whether technology is present. When combined with TPACK, the framework enables researchers to examine both teachers' technological-pedagogical competencies and the extent to which technology changes educational practices (Major & Francis, 2018). Consequently, TPACK and SAMR provide complementary conceptual tools for assessing the pedagogical maturity of Smart Pesantren.

Digital literacy constitutes another essential theoretical component of Smart Pesantren because technological access alone does not guarantee meaningful or responsible participation in digital environments. Digital literacy encompasses the ability to access, evaluate, interpret, produce, communicate, and ethically utilize digital information. In Islamic educational settings, these competencies require additional attention because *santri* increasingly encounter religious information through social media, websites, video platforms, digital libraries, and artificial-intelligence applications. Research conducted at Darunnajah Islamic Boarding School demonstrates that pesantren can develop digital literacy through structured activities involving digital media production and content creation while maintaining Islamic institutional values (Darajat et al., 2022). This finding indicates that digital literacy within pesantren should move beyond basic technical skills toward critical, creative, communicative, and ethical competencies. The implication is that Smart Pesantren should position digital literacy as a core educational outcome rather than treating it as an optional technical capability. Such an orientation would enable *santri* to participate actively and responsibly in contemporary digital society.

The epistemological dimension of digital literacy becomes particularly important in the context of Islamic education because digital environments contain an enormous amount of religious information with varying degrees of authority and credibility.

Students may encounter scholarly interpretations, popular religious opinions, misinformation, decontextualized quotations, and algorithmically generated content within the same digital environment. Therefore, digital literacy in pesantren must include the capacity to evaluate the reliability of information, identify authoritative Islamic sources, compare interpretations, and distinguish evidence-based scholarship from unsupported claims. The development of digital literacy through institutional programs at pesantren demonstrates that critical engagement with digital information can be cultivated through structured educational practices (Darajat et al., 2022). Such an approach is particularly relevant to Smart Pesantren because technological transformation should increase students' intellectual autonomy without weakening their methodological discipline in understanding religious knowledge. Digital literacy must therefore be connected with critical thinking, scholarly responsibility, and ethical communication. This conceptualization positions *santri* not merely as consumers of digital information but as critical and responsible producers of knowledge.

Organizational learning provides an additional theoretical foundation for understanding the sustainability of digital transformation within pesantren. Institutional transformation cannot depend solely on a small group of individuals who possess advanced technological competencies because digital transformation requires collective adaptation across organizational levels. A learning organization develops through continuous knowledge acquisition, shared vision, collaborative learning, systems thinking, and the willingness of organizational members to critically evaluate established practices. From this perspective, digital transformation should become part of the institutional learning process rather than being implemented as a temporary technological project. (Ali et al., 2025) Educational organizations that successfully integrate digital technologies generally require continuous professional development and organizational adaptation because technological environments change rapidly (Fernández et al., 2023). For pesantren, this means that *kyai*, administrators, *ustadz*, *santri*, and technical personnel should participate in continuous learning regarding the educational and organizational implications of emerging technologies. Smart Pesantren therefore requires not only digital infrastructure but also an institutional culture that supports learning, experimentation, reflection, and continuous improvement.

The organizational learning perspective is closely connected with the capacity of pesantren to preserve institutional traditions while responding to contemporary technological developments. Pesantren have historically demonstrated considerable institutional adaptability by incorporating new educational practices while maintaining core religious traditions. Digital transformation can therefore be interpreted as another stage in the continuing process of institutional adaptation. Rather than replacing traditional educational practices, digital systems can be used to document, disseminate, and enrich existing knowledge traditions. Digital libraries, electronic *kitab*, online discussion forums, and institutional repositories, for example, can extend access to classical and contemporary Islamic scholarship. Such integration requires organizational members to understand both the potential and limitations of digital technologies. The organizational learning perspective therefore suggests that successful Smart Pesantren development depends on the institution's ability to transform technological experiences into collective knowledge and sustainable institutional practices (Fernández et al., 2023). In this sense, digital maturity is not simply a technological condition but an organizational learning capability.

Digital leadership represents another critical dimension of Smart Pesantren development. Digital transformation requires institutional leaders who are capable of articulating a clear technological vision, mobilizing resources, encouraging innovation,

managing organizational resistance, and ensuring that technological development remains aligned with institutional objectives. In pesantren, leadership assumes particular importance because the *kyai* frequently possesses substantial influence over educational direction, institutional policy, and organizational culture. (Barton et al., 2021) Research on digital transformation in pesantren demonstrates that *kyai* leadership can contribute significantly to the development of digital educational services and institutional communication (Bahri et al., 2024). This finding suggests that digital transformation cannot be separated from the authority structure and leadership culture of pesantren. Technological initiatives that lack leadership support may encounter institutional resistance or fail to become integrated into long-term organizational strategies. Therefore, Smart Pesantren requires digital leadership that combines religious legitimacy, organizational vision, technological awareness, and change-management capacity.

The role of *kyai* leadership becomes increasingly significant when digital transformation is understood as a process of negotiating between tradition and innovation. Pesantren possess deeply rooted traditions concerning curriculum, teacher authority, student discipline, communal life, and religious learning. Digital technologies may challenge some of these established practices while simultaneously creating opportunities for institutional development. Transformational leadership can provide a mechanism through which technological innovation is introduced without undermining the fundamental values of pesantren. Studies of pesantren leadership indicate that *kyai* can function as strategic actors who mediate between traditional Islamic educational values and contemporary educational demands (Al Ayubbi, 2024). The relevance of this finding lies in its demonstration that digital transformation does not necessarily require the abandonment of traditional leadership. Instead, the authority of *kyai* can become an important institutional resource for directing technological innovation toward educational and ethical objectives. Consequently, digital leadership within Smart Pesantren should be understood as a process of value-based technological transformation rather than simply administrative technology management.

Institutional readiness provides an important analytical framework for determining whether a pesantren possesses the necessary conditions for digital transformation. Readiness includes technological infrastructure, financial resources, human-resource competence, leadership commitment, organizational policies, institutional culture, and the digital capabilities of teachers and students. (Ali et al., 2025) The presence of internet connectivity or digital devices does not necessarily indicate that an institution is prepared for comprehensive digital transformation. Educational transformation is influenced by the interaction between technological resources, organizational preparation, and human capabilities (Castro Benavides et al., 2020). This perspective is particularly relevant to pesantren because substantial differences exist in infrastructure, financial capacity, teacher competence, and institutional management across pesantren. Therefore, the development of Smart Pesantren should begin with a systematic assessment of institutional readiness. Such an assessment can identify technological gaps and ensure that digital interventions correspond to the actual needs and capacities of individual pesantren.

Institutional readiness also requires consideration of organizational culture and resistance to technological change. Technology adoption may encounter resistance when teachers perceive digital systems as additional workloads, when administrators lack confidence in technological management, or when institutional members fear that technology will undermine traditional educational practices. Digital transformation research indicates that organizational resistance, limited resources, inadequate competencies, and weak strategic coordination can impede the sustainability of

technological initiatives (Castro Benavides et al., 2020; Fernández et al., 2023). Within pesantren, these challenges may be intensified by the need to preserve religious traditions and institutional identity. Consequently, readiness should not be interpreted solely in terms of infrastructure but also as psychological, cultural, organizational, and strategic preparedness. A Smart Pesantren strategy should therefore incorporate capacity building, professional development, participatory decision-making, and institutional communication alongside technological investment.

The digital ecosystem perspective further expands the conceptualization of Smart Pesantren by emphasizing relationships among multiple institutional stakeholders. A pesantren operates within an ecosystem involving *kyai*, *ustadz*, *santri*, parents, alumni, communities, government agencies, universities, technology providers, and other educational institutions. (Erturk, 2022) Digital technologies can facilitate communication and collaboration among these actors through integrated information systems, learning platforms, alumni networks, digital admission systems, and community communication channels. Research on digital transformation in pesantren indicates that technology can strengthen institutional communication and educational services beyond the immediate classroom environment (Bahri et al., 2024). This perspective implies that Smart Pesantren should not be designed as an isolated digital campus but as an interconnected educational ecosystem. The effectiveness of digital transformation consequently depends on the ability of different actors and systems to communicate, exchange information, and coordinate their activities.

The ecosystem perspective also has implications for the development of sustainable partnerships. Universities can support pesantren through research, teacher training, curriculum development, and technological innovation, while technology providers can contribute infrastructure and technical expertise. Alumni networks can facilitate resource mobilization and professional mentoring, while government institutions can provide policy frameworks and support programs. Digital platforms create opportunities for these relationships to become more continuous and systematic. Such connectivity can strengthen pesantren's institutional capacity and reduce dependence on isolated technological projects. From an ecosystem perspective, Smart Pesantren should therefore be understood as a collaborative network rather than a technologically self-contained institution. The development of this ecosystem can contribute to institutional resilience by distributing knowledge, resources, expertise, and innovation across multiple stakeholders.

Adaptive learning provides a pedagogical perspective that can strengthen personalization within Smart Pesantren. Conventional instructional models often provide relatively similar learning materials and activities to students despite differences in prior knowledge, learning pace, language proficiency, academic interests, and technological competence. Digital learning environments offer opportunities to provide differentiated materials, feedback, exercises, and learning pathways according to students' needs. Adaptive learning can therefore complement collective learning traditions by providing individualized academic support. (Yani et al., 2022) However, personalization should not eliminate the central role of teachers because Islamic education emphasizes guidance, exemplary conduct, interpersonal relationships, and character formation. Smart Pesantren should consequently utilize adaptive technologies as complementary tools that support teacher-guided learning rather than as substitutes for the teacher. This approach maintains the relational character of Islamic education while taking advantage of the personalization capabilities of digital systems.

Data-informed educational management constitutes another important dimension of the Smart Pesantren framework. Digital management systems can collect and organize

information regarding attendance, academic achievement, learning activities, student services, library utilization, financial management, and institutional performance. Properly analyzed, such data can support evidence-based decision-making and improve the efficiency of institutional management. Data can also enable leaders to identify patterns, evaluate educational programs, allocate resources, and respond to emerging problems more effectively. However, the use of educational data creates ethical responsibilities concerning privacy, data security, consent, and appropriate access. Digital transformation should therefore avoid transforming educational data into excessive surveillance mechanisms. Smart Pesantren requires data governance principles that balance institutional accountability, administrative efficiency, and the rights and dignity of *santri*.

Blended learning provides a particularly appropriate pedagogical model for integrating digital technologies into pesantren education. The fundamental principle of blended learning is the combination of face-to-face educational interaction with digitally mediated learning activities. This approach is compatible with pesantren because direct interaction between *kyai*, *ustadz*, and *santri* remains essential to the transmission of knowledge, character, discipline, and religious values. (Nikmah & Nasikhin, 2025) Digital platforms can complement traditional learning activities by providing access to electronic *kitab*, recorded lessons, online discussions, digital assignments, collaborative resources, and supplementary learning materials. Consequently, digital learning should not be conceptualized as a replacement for *halaqah*, *sorogan*, *bandongan*, or *musyawarah*. Rather, technology can extend these educational practices beyond temporal and spatial limitations. The Smart Pesantren model should therefore develop a hybrid learning environment in which digital and physical learning spaces operate in a complementary manner.

Constructivist learning theory provides further justification for the use of digital technologies to promote active learning within pesantren. Constructivism conceptualizes learners as active participants who construct knowledge through experience, interaction, reflection, inquiry, and engagement with meaningful problems. Digital environments can facilitate these processes through collaborative platforms, multimedia resources, online discussions, project-based activities, simulations, and student-generated content. Such learning experiences can support higher-order cognitive processes by encouraging students to analyze information, evaluate arguments, solve problems, and produce new knowledge. These principles are compatible with established Islamic educational practices such as *musyawarah* and *bahtsul masail*, which emphasize dialogue, reasoning, argumentation, and collective problem solving. Digital technology can therefore strengthen existing participatory traditions rather than merely replacing conventional teaching materials. Smart Pesantren should consequently prioritize technology-supported learning designs that position *santri* as active participants in knowledge construction.

The normative foundation of Smart Pesantren ultimately rests upon Islamic pedagogy. Islamic education seeks not only to develop intellectual capabilities but also to cultivate faith, morality, character, discipline, and responsible action. Concepts such as *ta'lim*, *tarbiyah*, *ta'dib*, *adab*, and *akhlaq* provide philosophical principles for determining the educational value of technological innovation. From this perspective, technology cannot be regarded as educationally successful solely because it increases efficiency or access to information. Technological applications must also contribute to intellectual development, moral formation, spiritual awareness, and social responsibility. This normative orientation distinguishes Smart Pesantren from purely technology-driven models of smart education. Digital transformation should therefore remain subordinate to

the fundamental educational mission of pesantren, namely the formation of knowledgeable, ethical, spiritually grounded, and socially responsible individuals.

Digital ethics consequently represents an indispensable dimension of the Smart Pesantren framework. The rapid expansion of social media, artificial intelligence, digital communication, and data-driven systems creates new ethical challenges involving privacy, misinformation, intellectual property, academic integrity, cyberbullying, algorithmic bias, and online identity. These challenges cannot be addressed exclusively through technical regulations because students require moral frameworks that guide decision-making in complex digital situations. Islamic ethical principles such as honesty, responsibility, justice, moderation, respect, and the prevention of harm provide a strong normative foundation for responsible digital citizenship. Digital literacy programs in pesantren should therefore integrate ethical reasoning with technological skills so that students understand not only how technology works but also how it should be used responsibly. Smart Pesantren must ultimately produce digitally competent *santri* who can participate in digital society while maintaining Islamic ethical commitments.

Sustainability represents the final dimension necessary for understanding the long-term development of Smart Pesantren. Technological initiatives frequently experience difficulties when they depend on short-term projects, temporary funding, individual technological experts, or isolated institutional programs. Sustainable transformation requires institutional budgeting, infrastructure maintenance, continuous teacher development, technical support, cybersecurity policies, organizational regulations, and systematic evaluation. Research on digital transformation emphasizes that fragmented technological initiatives are less likely to produce sustainable institutional change when they are not integrated into comprehensive organizational strategies (Fernández et al., 2023). This issue is particularly important for pesantren because technological infrastructure requires continuous updating and human resources require ongoing professional development. Therefore, Smart Pesantren should be developed as a long-term institutional strategy rather than a temporary modernization project.

The concept of smart education provides an integrative technological perspective for understanding how connectivity, data, personalization, intelligent systems, and responsive educational services can support institutional development. Nevertheless, the concept of smart education cannot simply be transferred from conventional schools to pesantren without contextual adaptation. The residential, communal, religious, and cultural characteristics of pesantren require technological solutions that respond specifically to their institutional needs. Digital systems may support academic administration, student services, digital libraries, communication, learning management, scheduling, and other institutional functions while remaining integrated with pesantren routines. Digital transformation research demonstrates that emerging technologies can restructure educational practices and institutional services when appropriately aligned with organizational contexts (Mukul & Büyüközkan, 2023). Thus, Smart Pesantren should be understood as a context-sensitive form of smart education in which technological intelligence is integrated with Islamic educational values and institutional traditions.

The preceding theoretical perspectives can be synthesized into an integrated conceptual framework for Smart Pesantren. Digital transformation provides the overarching institutional framework, while educational technology integration explains the relationship between technological resources and pedagogical practice. Digital literacy and adaptive learning address the competencies and learning needs of *santri*, whereas organizational learning, institutional readiness, and digital leadership explain the



organizational conditions required for transformation. Blended learning and constructivist pedagogy provide mechanisms for redesigning learning experiences, while data-informed management and ecosystem development strengthen institutional governance and stakeholder connectivity. Islamic pedagogy and digital ethics provide the normative foundation that ensures technological development remains consistent with the educational mission and religious identity of pesantren. Accordingly, Smart Pesantren should be understood as an integrated institutional ecosystem rather than as a collection of technological applications.

Based on this synthesis, the Smart Pesantren framework can be conceptualized through six mutually reinforcing dimensions: digital infrastructure, digital pedagogy, digital leadership, digital governance, digital literacy, and Islamic digital ethics. Digital infrastructure provides the technological foundation, whereas digital pedagogy determines how technology contributes to meaningful learning. Digital leadership establishes strategic direction and institutional commitment, while digital governance ensures accountability, interoperability, security, and sustainability. Digital literacy develops the capacity of teachers and *santri* to access, evaluate, create, and communicate information responsibly, while Islamic digital ethics establishes moral boundaries for technological use. These dimensions should not be treated as independent components because weaknesses in one dimension can limit the effectiveness of the others. The resulting framework therefore conceptualizes Smart Pesantren as a digitally adaptive, pedagogically innovative, ethically grounded, and institutionally sustainable Islamic educational ecosystem capable of responding to contemporary technological change without abandoning its distinctive educational identity

Method

This study employed library research as the primary methodological approach. Library research is appropriate for examining conceptual developments and synthesizing existing scholarly evidence across multiple research traditions. The study did not collect primary interview, survey, or observational data because its purpose was to construct a theoretical framework for Smart Pesantren from existing literature. Recent research on pesantren digital transformation has similarly used literature-based approaches to identify patterns and strategies in digitalization (Pratama et al., 2025; Rohana et al., 2026). This methodological choice is relevant because Smart Pesantren is an emerging concept requiring conceptual synthesis across educational technology, Islamic education, management, and digital transformation.

The literature search focused primarily on peer-reviewed journal articles published during the previous five to ten years, with particular emphasis on studies published from 2018 to 2026. The temporal focus was designed to capture recent developments in digital transformation, educational technology, artificial intelligence, digital literacy, and pesantren digitalization. Older foundational works were used only when necessary to explain established theoretical frameworks such as TPACK, SAMR, constructivism, or learning organization. Recent literature was prioritized because technology and digital education change rapidly. This strategy increases the contemporary relevance of the proposed Smart Pesantren model.

Search terms included "pesantren digital transformation," "Islamic boarding school digitalization," "Smart Pesantren," "educational technology pesantren," "digital literacy pesantren," "digital leadership pesantren," "e-learning pesantren," "Islamic education technology integration," "TPACK pesantren," "digital governance pesantren," and "smart education." Related English-language keywords were also used to identify international research concerning digital transformation, technology integration, digital



competence, educational ecosystems, and institutional readiness. The search strategy was designed to capture both specifically pesantren-focused studies and broader educational technology literature that could provide theoretical support. This approach is relevant because Smart Pesantren is inherently interdisciplinary.

The inclusion criteria consisted of studies that addressed educational technology, digital transformation, digital literacy, digital leadership, technology integration, Islamic education, pesantren, or closely related educational issues. Studies were prioritized when they provided empirical findings, systematic reviews, conceptual models, or documented cases of technology implementation. Articles were excluded when they had no substantive educational relevance or when their use of "digital" referred only to superficial communication without institutional or pedagogical implications. This screening process was necessary because the term digital transformation is frequently used loosely. The methodological objective was therefore to distinguish genuine transformation from simple digitization.

The selected literature was analyzed through thematic synthesis. Each study was examined for its research objectives, methodological approach, educational context, technology dimension, major findings, challenges, and implications. The information was then grouped into recurring themes such as infrastructure, pedagogy, digital literacy, leadership, governance, teacher competence, student development, ethics, data, and sustainability. This thematic approach is consistent with recent literature reviews that organize digital transformation around interconnected institutional dimensions rather than individual technologies (Castro Benavides et al., 2020; Fernández et al., 2023). The approach allows apparently separate studies to be interpreted as components of a larger institutional transformation process.

The analysis also considered methodological diversity among the selected studies. The reviewed literature included library research, systematic literature reviews, qualitative case studies, mixed-method studies, participatory research, and technology-development studies. Different methods provide different forms of evidence, so findings were not treated as statistically equivalent. Case studies were particularly useful for understanding how individual pesantren implement technology, while literature reviews were useful for identifying broader patterns. Technology-development studies were used to illustrate practical applications such as IoT-based institutional systems. This methodological triangulation strengthens the conceptual framework by combining institutional, pedagogical, and technological perspectives. Finally, the literature was synthesized into a conceptual Smart Pesantren framework. The framework was developed by identifying common dimensions across the literature and determining their relationships. Six core dimensions emerged: digital infrastructure, digital pedagogy, digital governance, human digital competence, Islamic digital literacy and ethics, and sustainable institutional innovation. The framework was then connected to institutional outcomes such as learning quality, administrative efficiency, student development, communication, institutional competitiveness, and community engagement. The resulting model is conceptual and therefore requires empirical testing through future case studies, surveys, experiments, and design-based research. Its methodological contribution lies in translating fragmented findings into an integrated framework for further investigation.

Results and Discussion

The synthesis of the literature indicates that digital transformation has increasingly become part of the institutional development of pesantren, although its implementation remains uneven across educational contexts. Existing studies document the adoption of digital media, administrative information systems, online communication platforms,

electronic learning resources, digital literacy programs, and technology-supported instructional practices. The variation in the intensity of digital transformation is associated with differences in technological infrastructure, leadership commitment, teacher competence, institutional policy, financial capacity, and organizational culture. For example, research on pesantren in Samarinda indicates that digital media have been utilized to support information dissemination and institutional management, demonstrating that technological practices are gradually becoming embedded within pesantren activities (Wijaya et al., 2024). Similar patterns have been identified in other studies that report the growing use of digital platforms for educational and administrative purposes. These findings suggest that digital transformation in pesantren should not be conceptualized as a binary condition in which institutions are either digital or non-digital, but rather as a continuum of institutional digital maturity.

The variation in digital maturity further indicates that the transformation of pesantren should be approached through an institutional rather than an application-oriented perspective. The presence of a learning management system, institutional website, social-media account, or digital administration platform does not necessarily demonstrate that an institution has achieved comprehensive digital transformation. Digital initiatives may remain fragmented when individual applications operate independently without interoperability, shared data structures, institutional policies, or strategic coordination. Research on digital transformation in educational institutions shows that many organizations remain at relatively early stages of digital maturity because technological initiatives are frequently implemented without sufficient integration into institutional strategies (Fernández et al., 2023). This observation is highly relevant to pesantren because a digital application may coexist with predominantly manual administrative processes and conventional instructional practices. The development of Smart Pesantren therefore requires an integrated digital architecture in which educational, administrative, communication, and student-service systems are interconnected through a coherent institutional strategy.

The availability and quality of digital infrastructure constitute a fundamental prerequisite for the implementation of Smart Pesantren. Reliable internet connectivity, local networks, computing devices, audiovisual equipment, servers or cloud services, stable electricity, cybersecurity mechanisms, and technical support determine the extent to which digital systems can operate consistently. Nevertheless, infrastructure development should not be understood merely as a process of increasing the quantity of technological equipment. Infrastructure must be aligned with institutional priorities, financial capacity, maintenance capabilities, and the actual educational needs of pesantren. Recent research indicates that limitations in technological infrastructure continue to represent an important obstacle to digitalization in traditional pesantren (Mufadhol et al., 2025). This finding has important policy implications because technology strategies based exclusively on expensive and sophisticated infrastructure may unintentionally widen the digital divide among pesantren. Smart Pesantren development should therefore emphasize scalable, affordable, interoperable, and sustainable technological solutions that can be adapted to different levels of institutional capacity.

Beyond infrastructure, the educational value of digital transformation depends fundamentally on the quality of pedagogical integration. Technology contributes meaningfully to education when it facilitates active learning, expands access to knowledge, improves feedback mechanisms, supports collaboration, or enables learning experiences that are difficult to achieve through conventional approaches. Research on pesantren in East Java demonstrates that technological innovation can contribute to

learning effectiveness when it is embedded within appropriate educational management and pedagogical practices (Abidin et al., 2025). This finding reinforces the principle that technological procurement should follow educational objectives rather than determine them. In practical terms, institutional leaders and teachers should begin digital planning by identifying specific educational problems, such as limited access to learning resources, difficulties in monitoring student progress, or insufficient opportunities for collaborative learning. Technology can then be selected according to its capacity to address these problems effectively and sustainably.

The development of digital literacy among *santri* emerges as another significant outcome of digital transformation. Contemporary students increasingly operate within digital environments in which learning, communication, religious discourse, entertainment, and social interaction overlap. Consequently, digital competence must encompass more than the ability to operate devices or applications. It should include information evaluation, critical thinking, digital communication, content production, online safety, ethical behavior, and responsible participation in digital communities. Research conducted at Darunnajah Islamic Boarding School demonstrates that structured digital literacy activities involving content creation, video production, and Islamic journalism can transform students from passive consumers into active digital producers (Darajat et al., 2022). This finding is particularly significant for Smart Pesantren because it demonstrates that digital literacy can be developed without disconnecting students from their religious identity. Instead, technological competencies can be integrated with Islamic communication, *dakwah*, and knowledge-production activities.

Digital literacy also creates opportunities to strengthen the intellectual traditions of pesantren through contemporary information environments. The scholarly tradition of pesantren has historically emphasized the study of classical Islamic texts, discussion, interpretation, memorization, and collective intellectual inquiry. Digital libraries, electronic *kitab*, searchable databases, online repositories, and scholarly communication platforms can expand access to these resources while preserving the substance of traditional learning. Digital tools can facilitate the comparison of different editions of classical texts, the identification of relevant references, and the documentation of scholarly discussions. Such applications are particularly valuable for activities such as *bahtsul masail*, where students are required to examine textual evidence and develop reasoned responses to contemporary problems. The integration of digital resources with traditional intellectual practices therefore illustrates how digital transformation can strengthen rather than replace the epistemological traditions of pesantren. Smart Pesantren should consequently position technology as an instrument for extending the intellectual capacity of *santri*.

The digital transformation of pesantren also has implications for the geographical boundaries of educational participation. Historically, the educational influence of a pesantren has been strongly associated with its physical campus and residential community. Digital platforms, however, enable educational content, institutional information, and selected services to reach alumni, parents, prospective students, community members, and broader audiences beyond the physical institution. Research concerning the digital transformation of pesantren has identified this development as a form of educational deterritorialization in which digital environments extend institutional interaction beyond geographical boundaries (Maram & Fanani, 2025). This development creates opportunities for online *dakwah*, alumni engagement, lifelong learning, public communication, and continuing education. The implication is that Smart Pesantren can evolve from a physically bounded educational institution into a networked educational

ecosystem. Such transformation can increase institutional visibility while simultaneously strengthening relationships between pesantren and their wider communities.

The use of digital technology in Qur'anic and religious learning illustrates both the opportunities and limitations of technological integration. Digital applications can support memorization, recitation practice, learning-resource distribution, assessment, and monitoring of students' progress. Technology can also provide teachers with organized records that make it easier to identify learning difficulties and provide targeted interventions. Recent research concerning digital approaches to *tahfiz* evaluation indicates that technology can facilitate more systematic monitoring of Qur'anic learning processes (Sekolah et al., 2025). Nevertheless, the use of technology should not be interpreted as a substitute for the pedagogical and spiritual functions of the *ustadz*. Qur'anic learning involves pronunciation, interpretation, discipline, character formation, emotional guidance, and spiritual orientation, many of which depend on interpersonal relationships. Therefore, the most appropriate Smart Pesantren model is one in which technology supports monitoring, accessibility, and feedback while teachers retain responsibility for pedagogical, moral, and spiritual guidance.

Institutional leadership emerges consistently in the literature as a decisive factor in determining the direction and sustainability of digital transformation. Technological adoption requires leaders to establish a clear institutional vision, formulate policies, allocate resources, develop human capacity, and establish mechanisms of accountability. Within pesantren, this role is particularly important because the *kyai* often exercises substantial influence over institutional priorities and organizational culture. Bahri et al. (2024) demonstrate that *kyai* leadership can facilitate the adoption of digital technologies to improve educational services and institutional communication. This finding indicates that technological transformation is more likely to become institutionalized when it is supported by formal leadership rather than depending solely on individual teacher initiatives. Digital transformation should therefore begin with a shared institutional vision concerning the role of technology in improving educational quality. Smart Pesantren requires leadership that is capable of connecting technological innovation with the religious, pedagogical, and organizational mission of the institution.

Teacher competence represents another critical determinant of whether digital transformation produces meaningful educational outcomes. The availability of sophisticated technological infrastructure does not automatically translate into effective classroom integration because teachers must possess the knowledge and confidence required to select, implement, evaluate, and adapt digital tools. Research on teacher digital competence demonstrates that effective technology integration requires multiple dimensions of competence, including technical proficiency, pedagogical knowledge, collaboration, professional development, and the ability to use digital resources critically (Basilotta-Gómez-Pablos et al., 2022). This requirement becomes more complex in pesantren because teachers may be responsible for both Islamic and general education subjects, each with different pedagogical and technological requirements. Professional development should therefore move beyond short-term technical workshops toward sustained programs focused on authentic classroom integration. Such programs should enable *ustadz* to design technology-supported learning activities that remain consistent with curriculum objectives and Islamic educational values.

Curriculum integration is consequently essential to prevent digital competence from becoming isolated within specific information-technology subjects. Digital competencies should be embedded across the curriculum so that students learn to use technology as part of authentic disciplinary and intellectual activities. Within Islamic education, for example, students can utilize digital databases to examine Qur'anic



interpretations, electronic *kitab* to investigate fiqh questions, online scholarly resources to compare Hadith commentaries, and digital collaborative platforms to conduct *bahtsul masail*. Similar integration can occur within Arabic language learning, Islamic history, science, mathematics, entrepreneurship, and social studies. Recent conceptual work has proposed combining TPACK and SAMR to support the development of digitally adaptive pesantren curricula, emphasizing the relationship between teacher competence and the depth of technological integration (Raafi & Saifulloh, 2026). This approach is valuable because it shifts curriculum development away from technology as a separate subject toward technology as an integrated means of achieving disciplinary and educational objectives. Consequently, curriculum transformation represents one of the most important mechanisms through which Smart Pesantren can move from basic digitalization toward meaningful educational transformation. The integrated findings can be summarized in the following Smart Pesantren framework.

Smart Pesantren Dimension	Main Technology Component	Educational/ Institutional Function	Islamic Value Orientation	Expected Outcome
Digital Infrastructure	Internet, cloud, devices, networks, IoT	Reliable access and connectivity	Efficiency and responsibility	Digital readiness
Digital Pedagogy	LMS, multimedia, e-books, blended learning	Improve teaching and learning	Ta'lim and tarbiyah	Better learning quality
Digital Literacy	Digital libraries, media production, information evaluation	Develop critical digital users	Adab and amanah	Responsible santri
Digital Leadership	Digital strategy, policy, dashboards	Institutional transformation	Shura and accountability	Strong governance
Digital Governance	EMIS/SIM, finance, attendance, data systems	Administrative efficiency	Transparency and trust	Institutional intelligence
Digital Islamic Learning	Qur'an apps, Hadith databases, digital <i>kitab</i>	Expand Islamic learning resources	Preservation of turath	Richer religious learning
Adaptive Learning	Analytics, personalized platforms	Respond to learner differences	Justice and maslahat	Personalized learning
Digital Ethics	Cybersecurity, privacy, content guidelines	Prevent misuse and harm	Akhlaq and responsibility	Ethical digital behavior



Smart Pesantren Dimension	Main Technology Component	Educational/ Institutional Function	Islamic Value Orientation	Expected Outcome
Smart Facilities	IoT, automated systems, smart classrooms	Improve operational services	Efficiency and discipline	Smart institutional environment
Sustainable Innovation	Partnerships, training, evaluation	Maintain transformation	Islah and continuous improvement	Sustainable digital maturity

The proposed Smart Pesantren framework demonstrates that digital transformation should be understood as an interconnected institutional process rather than as the implementation of an individual technological project. Its effectiveness depends on the interaction among infrastructure, digital pedagogy, teacher competence, student literacy, leadership, governance, Islamic values, and institutional sustainability. Technological infrastructure without adequate human competence may result in underutilized systems, while pedagogical innovation without appropriate governance may generate fragmented platforms and inconsistent educational practices. Similarly, strong institutional leadership may fail to produce meaningful outcomes when students and teachers lack the digital competencies required to use technology productively and responsibly. Conversely, the preservation of Islamic values without technological adaptation may limit the capacity of *santri* to participate effectively in contemporary society. These relationships indicate that Smart Pesantren should be conceptualized as a holistic educational ecosystem in which technological, pedagogical, organizational, and ethical dimensions mutually reinforce one another.

Digital infrastructure constitutes the foundational layer upon which the broader Smart Pesantren ecosystem is constructed. Infrastructure encompasses internet connectivity, computing devices, software, learning platforms, electricity, technical support, cybersecurity mechanisms, data storage, and system interoperability. Nevertheless, infrastructure development should not be pursued through a technology-first approach because pesantren differ substantially in institutional size, geographical location, financial capacity, student population, and educational priorities. Research concerning digitalization in traditional pesantren indicates that infrastructure limitations remain a significant challenge, particularly for institutions operating with constrained resources (Mufadhol et al., 2025). This condition suggests that technological modernization should prioritize reliability, affordability, scalability, and sustainability rather than technological sophistication alone. A small pesantren with stable internet access, a cloud-based learning platform, and an effective administrative system may achieve greater educational value than an institution possessing sophisticated hardware that is poorly utilized. Consequently, the appropriate infrastructure for Smart Pesantren is determined by educational usefulness and institutional sustainability rather than by technological complexity.

The educational significance of infrastructure becomes apparent when technological resources are translated into meaningful pedagogical practices. Digital pedagogy requires teachers to redesign learning experiences so that technology facilitates inquiry, collaboration, reflection, problem solving, creativity, and access to diverse sources of knowledge. Digital textbooks, multimedia materials, interactive presentations, online discussion forums, learning management systems, and digital assessment tools can complement established pesantren learning traditions such as *halaqah* and *sorogan*.

Research on digital technology in Islamic education indicates that technological integration can increase student engagement and facilitate deeper understanding when it is supported by appropriate pedagogical strategies (Siregar et al., 2025). This finding demonstrates that the educational value of technology lies not in its presence but in how it transforms the relationship between teachers, students, knowledge, and learning activities. Smart Pesantren should therefore prioritize pedagogical transformation over the simple conversion of printed materials into electronic formats.

The integration of technology also creates an opportunity to preserve and revitalize the intellectual heritage of pesantren, particularly the tradition of *turath* scholarship. Classical Islamic texts, commonly transmitted through *kitab kuning* and teacher-mediated learning, constitute a central component of pesantren intellectual culture. Digital libraries, searchable databases, electronic manuscripts, and classical-text applications can expand access to these sources while enabling students to conduct more systematic searches and comparative studies. Research indicates that digital resources such as Maktabah Syamilah and online classical-text collections have increasingly become part of literacy practices within pesantren (Waqiyulloh & Dini, 2024). This development suggests that digitalization does not necessarily represent a departure from traditional Islamic scholarship. Instead, digital technology can provide new instruments for preserving, accessing, organizing, and disseminating the intellectual heritage of pesantren. Smart Pesantren should therefore approach digitalization as a mechanism for revitalizing *turath* through contemporary knowledge infrastructures, rather than as an attempt to replace traditional Islamic scholarship.

The transformation of Islamic learning further requires the development of digital Islamic literacy as a specific educational competency. The abundance of religious information available through social media, video platforms, websites, online forums, and artificial-intelligence systems creates both opportunities and epistemological risks. Students need the capacity to evaluate information according to source credibility, contextual relevance, scholarly authority, textual evidence, and ethical considerations. This competency is especially important because digital religious content can be produced and disseminated rapidly without passing through established mechanisms of scholarly verification. Research on digital literacy in pesantren emphasizes the strategic role of Islamic educational institutions in preparing critical and productive Muslim generations capable of navigating digital environments while maintaining Islamic ethical principles (Pratama et al., 2025). Accordingly, digital Islamic literacy should not be treated as a supplementary technological skill but as an integral component of contemporary religious education. Its ultimate purpose is to develop *santri* who can engage with digital religious discourse critically, responsibly, and intellectually.

Digital transformation should also position *santri* as producers of knowledge and Islamic digital content rather than merely consumers of information. Contemporary digital environments provide opportunities for students to communicate ideas through podcasts, educational videos, digital magazines, infographics, documentaries, Islamic journalism, websites, and other forms of multimedia production. Such activities can simultaneously develop technological competence, communication skills, creativity, teamwork, critical thinking, and ethical awareness. Research at Darunnajah Islamic Boarding School demonstrates that structured digital content-production activities can strengthen students' digital capabilities and encourage more active participation in digital environments (Darajat et al., 2022). From an educational perspective, content creation also transforms students from passive recipients of religious messages into participants in the dissemination of Islamic knowledge. Smart Pesantren can therefore use digital content

production as a pedagogical strategy for connecting Islamic scholarship with contemporary communication practices.

The institutionalization of digital systems requires a governance structure capable of coordinating technological resources, organizational processes, and ethical responsibilities. Digital governance encompasses academic administration, student registration, attendance management, financial services, library systems, communication, reporting, data management, and student services. When properly designed, these systems can improve efficiency, transparency, accessibility, and institutional accountability. However, digitalization can also introduce new risks related to unauthorized access, data loss, cybersecurity, privacy violations, and inappropriate information sharing. Research on digitalized pesantren management identifies both improvements in administrative efficiency and challenges associated with security and governance (Muhammad et al., 2025). This evidence indicates that Smart Pesantren cannot be reduced to the adoption of digital applications; it requires institutional policies that define responsibilities, access rights, security procedures, data protection, and accountability. Digital governance should consequently become an integral component of pesantren management rather than an administrative consequence of technological adoption.

The role of *kyai* leadership remains central to the institutionalization of digital transformation within pesantren. Leadership influences whether technology is interpreted as a threat to traditional educational practices, an external disruption, or an opportunity to strengthen institutional capacity. A digitally aware *kyai* can articulate the strategic purposes of technology while establishing appropriate boundaries concerning its use, thereby creating a balance between innovation and institutional discipline. Research demonstrates that *kyai* leadership can facilitate the adoption of digital technologies to improve educational services and institutional communication (Bahri et al., 2024). This suggests that digital transformation requires more than technical expertise at the operational level; it requires leadership that can connect technological innovation with the mission and values of pesantren. Digital leadership should therefore be incorporated into institutional development programs for *kyai* and pesantren administrators, particularly in areas such as strategic planning, digital governance, innovation management, and ethical technology use.

Teacher professional development represents a complementary requirement because institutional digital transformation cannot succeed without pedagogically competent teachers. Professional development should move beyond basic computer literacy toward the ability to design technology-supported learning experiences, formulate digital learning objectives, select appropriate technological tools, develop digital assessments, facilitate online interaction, and protect student information. The TPACK framework is particularly relevant because it emphasizes the interaction among technological knowledge, pedagogical knowledge, and content knowledge in effective technology integration (Major & Francis, 2018). Within pesantren, this integration becomes more complex because teachers frequently operate across religious and general educational domains. Professional development should therefore include context-specific activities in which *ustadz* develop digital learning materials for Qur'anic studies, Hadith, Fiqh, Arabic, Islamic history, and other disciplines. Such an approach would transform teacher development from short-term technical training into sustained professional learning oriented toward meaningful pedagogical transformation.

The personalization of learning represents another potential contribution of Smart Pesantren through adaptive learning technologies. Digital systems can potentially analyze students' learning progress and provide recommendations concerning learning materials, exercises, assessments, and remedial activities. This capability may be particularly

valuable because *santri* differ in prior knowledge, learning pace, language proficiency, academic interests, and technological competencies. Nevertheless, personalization should not be interpreted as a justification for reducing the role of teachers or replacing interpersonal educational relationships. Teachers remain essential for mentoring, character development, spiritual formation, contextual interpretation, and the transmission of values. The integration of adaptive learning with organizational learning has been proposed as a possible direction for pesantren digital transformation (Manaf et al., 2026). Accordingly, adaptive technology should be positioned as a decision-support and learning-support mechanism within a human-centered Islamic educational ecosystem.

The application of smart technologies can also extend beyond classroom instruction to the physical management of pesantren facilities. Internet of Things technologies may support selected institutional functions such as announcements, scheduling, environmental monitoring, energy management, attendance systems, security, and facility maintenance. Research on an IoT-based smart audio system demonstrates the possibility of developing focused technological solutions that respond directly to the operational characteristics of pesantren (Bashir et al., 2026). Such applications illustrate that smart technology does not necessarily require a technologically complex environment encompassing every institutional activity. Instead, technological intelligence can begin with relatively simple systems that address clearly identified institutional problems. This finding reinforces the principle that Smart Pesantren should be guided by contextual technological appropriateness, whereby technology is selected according to institutional needs, usability, cost, and educational value.

As digital systems become increasingly embedded in institutional operations, cybersecurity and privacy become fundamental dimensions of Smart Pesantren governance. Digital transformation increases the amount of personal and institutional information stored electronically, including student records, attendance data, academic performance, financial information, parental contacts, and other administrative records. The protection of such information requires technical measures as well as institutional policies concerning authentication, authorization, password management, device security, data backup, access control, and responsible information sharing. Concerns regarding data security have increasingly appeared in discussions of educational digitalization, including within Islamic educational institutions. Consequently, cybersecurity should not be treated merely as a technical responsibility assigned to information-technology personnel. It should become part of the institutional culture in which *kyai*, teachers, administrators, and *santri* understand their respective responsibilities for protecting digital information.

The ethical dimension of digital transformation provides Smart Pesantren with a distinctive normative foundation. Islamic ethical concepts such as *amanah*, *sidq*, *adl*, *rahmah*, and *maslahah* can provide principles for evaluating how digital technologies are used and how individuals behave within digital environments. The concept of *amanah*, for example, can inform responsible data management, while *sidq* can guide students in avoiding misinformation and deceptive digital content. Similarly, *adl* can inform discussions concerning fairness and algorithmic decision-making, whereas *maslahah* can be used to evaluate whether a technological innovation genuinely contributes to educational benefit. Research on digital literacy in pesantren emphasizes the importance of aligning technological competencies with Islamic ethical values (Pratama et al., 2025). This integration distinguishes Smart Pesantren from technology-centered institutional models that evaluate digital transformation primarily according to efficiency, speed, and productivity. Technology in Smart Pesantren should ultimately be assessed according to

its contribution to educational benefit, human dignity, moral development, and institutional responsibility.

The relationship between technological restriction and digital empowerment presents a particularly important challenge for pesantren. Some institutions restrict students' access to personal devices because of concerns regarding distraction, inappropriate content, excessive social-media use, and declining discipline. Other institutions adopt more permissive approaches by incorporating personal and institutional devices into educational activities. Research on digital literacy practices in Indonesian pesantren demonstrates the coexistence of these different approaches, reflecting the continuing negotiation between institutional discipline and technological opportunity (Darajat et al., 2022). The Smart Pesantren framework proposes neither unrestricted technological access nor absolute technological restriction. Instead, it advocates controlled, purposeful, supervised, and educationally justified technology use. The objective is to cultivate responsible digital agency so that students gradually develop the capacity to regulate their own technological behavior in accordance with educational and Islamic ethical principles.

Digital transformation also offers opportunities to reinterpret traditional pesantren learning methods without eliminating their underlying pedagogical logic. *Sorogan*, for example, can be supported through digital recordings, individualized feedback, and digital learning portfolios, while *bandongan* can be complemented by electronic texts and supplementary multimedia resources. *Halaqah* can be extended through moderated digital discussion environments, while *bahtsul masail* can utilize searchable databases, collaborative research platforms, and digital repositories of Islamic scholarship. These adaptations do not necessarily alter the fundamental purposes of the traditional methods; rather, they expand the resources and learning environments through which those purposes can be achieved. Research on the interaction between technological innovation and pesantren traditions supports the possibility of adapting established educational practices to contemporary digital environments. The appropriate principle is therefore continuity through innovation, in which technology strengthens existing educational traditions instead of imposing cultural replacement.

The networked character of digital technology also creates new possibilities for community and alumni engagement. Digital platforms can connect pesantren with alumni, parents, scholars, universities, community organizations, governmental institutions, and international educational networks. Alumni, for instance, can participate through online mentoring, professional development, collaborative research, scholarships, internships, fundraising, and career networks. Parents can obtain more timely information regarding academic activities and student development, while external communities can access selected educational and religious content. Research on digital transformation in pesantren indicates that online environments can extend educational interaction beyond the physical boundaries of residential institutions (Maram & Fanani, 2025). Consequently, Smart Pesantren can develop into a networked lifelong-learning community in which educational relationships continue beyond the period of residential study.

Digital transformation may also strengthen institutional competitiveness, although competitiveness must be conceptualized carefully within the context of Islamic education. Technological sophistication alone should not determine the quality or reputation of a pesantren because the fundamental objectives of pesantren include intellectual development, moral formation, religious scholarship, social responsibility, and community service. Digital systems can nevertheless strengthen institutional efficiency, communication, educational services, public visibility, and stakeholder engagement.



Research on digital leadership and pesantren transformation suggests that ICT adoption can contribute to institutional competitiveness when supported by leadership, organizational capacity, and strategic planning. This finding indicates that digital transformation can enhance institutional identity when technology is used to strengthen educational quality rather than simply to improve institutional marketing. Therefore, the competitiveness of Smart Pesantren should be evaluated through multidimensional indicators encompassing academic quality, *akhlaq*, scholarly credibility, graduate competence, stakeholder trust, technological capacity, and institutional sustainability.

Sustainability is another fundamental consideration because digital transformation generates recurrent rather than one-time costs. Hardware requires maintenance and replacement, software requires updating, internet services require continuous financing, cybersecurity systems require monitoring, and teachers require ongoing professional development. A digital system that functions effectively during an initial project but becomes unusable after external funding ends cannot be considered a successful model of institutional transformation. Digital transformation literature consistently identifies financial constraints and insufficient long-term planning as important barriers to sustainable technology adoption. Smart Pesantren should therefore employ phased implementation strategies based on institutional priorities and available resources. Partnerships with universities, government agencies, alumni associations, technology providers, and community organizations may provide additional mechanisms for resource mobilization and capacity development.

Artificial intelligence represents an emerging frontier that may substantially reshape the Smart Pesantren ecosystem. AI technologies can potentially support translation, tutoring, content development, administrative automation, learning analytics, information retrieval, and personalized learning. At the same time, AI introduces significant concerns related to hallucinated information, misinformation, academic integrity, authorship, privacy, algorithmic bias, and the reliability of generated religious content. These concerns are particularly important in Islamic education because questions of religious authority, textual accuracy, and scholarly interpretation require rigorous verification. Recent discussions of digital transformation in pesantren increasingly identify artificial intelligence as an emerging component of contemporary Islamic education. Consequently, AI should be introduced through clear institutional policies, teacher supervision, source verification, academic-integrity standards, and explicit educational purposes. Smart Pesantren should adopt a human-supervised AI model in which artificial intelligence supports learning and administration without becoming an uncontrolled substitute for teachers or recognized sources of Islamic scholarship.

The long-term effectiveness of Smart Pesantren also depends on the development of a systematic digital-maturity evaluation framework. Institutions need mechanisms for determining whether technological investments actually produce improvements in educational quality, administrative efficiency, student engagement, and institutional services. Relevant indicators may include teacher digital competence, student digital literacy, system utilization, learning engagement, administrative efficiency, cybersecurity compliance, stakeholder communication, infrastructure reliability, and financial sustainability. Digital transformation research indicates that institutions frequently implement technological initiatives without sufficiently integrated strategic frameworks or systematic maturity assessments (Fernández et al., 2023). This condition makes continuous evaluation essential for identifying gaps and adjusting institutional strategies. Smart Pesantren should consequently adopt an iterative model of planning, implementation, evaluation, reflection, and improvement rather than treating digital transformation as a completed project.



The comprehensive analysis ultimately indicates that the philosophical orientation of Smart Pesantren is more important than the quantity of technology deployed. The objective of digital transformation should not be to transform pesantren into technologically saturated institutions but to strengthen their educational, intellectual, social, and spiritual missions through responsible technological innovation. A meaningful Smart Pesantren model must therefore be human-centered, pedagogically purposeful, ethically grounded, culturally responsive, technologically adaptive, and institutionally sustainable. The integration of technology with Islamic values should be viewed as a process of educational *islah*, in which technological innovation contributes to the continuous improvement of educational practices while preserving the essential identity of pesantren. The proposed framework consequently brings together institutional intelligence, digital competence, pedagogical innovation, Islamic identity, ethical governance, and technological integration within a single conceptual model. This integrative orientation constitutes the principal conceptual contribution of the study, because it positions Smart Pesantren not merely as a digitally equipped Islamic boarding school, but as an intelligent, adaptive, ethical, and sustainable Islamic educational ecosystem.



Conclusion

Digital transformation has become an increasingly important agenda for Islamic boarding schools because pesantren operate within a society in which learning, communication, administration, and religious information are increasingly mediated by digital technology. The literature reviewed in this study demonstrates that technology can strengthen pesantren learning, Qur'anic education, digital literacy, institutional management, communication, community engagement, and educational services. However, digitalization should not be equated with transformation because technology alone cannot guarantee educational improvement. The effectiveness of digital transformation depends on leadership, teacher competence, infrastructure, curriculum integration, institutional governance, cybersecurity, digital ethics, and sustainable innovation. The central finding of this study is that Smart Pesantren should be developed as an integrated educational ecosystem in which technology strengthens the distinctive educational mission of pesantren.

The principal novelty of this study is the proposed Smart Pesantren framework consisting of interconnected dimensions of digital infrastructure, digital pedagogy, digital literacy, digital leadership, digital governance, Islamic digital learning, adaptive learning, digital ethics, smart facilities, and sustainable innovation. The framework positions the kyai and educators as strategic leaders rather than allowing technology to become the institutional driver. It also emphasizes that the preservation of *turath*, *adab*, character formation, teacher-student relationships, and communal learning should remain central to transformation. Because this study is based on library research, the proposed framework should be empirically tested through comparative case studies, design-based research, longitudinal studies, and quantitative evaluations of digital maturity. Future research should particularly investigate the relationship between Smart Pesantren implementation and student learning outcomes, religious literacy, character development, teacher digital competence, institutional efficiency, and community engagement.



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